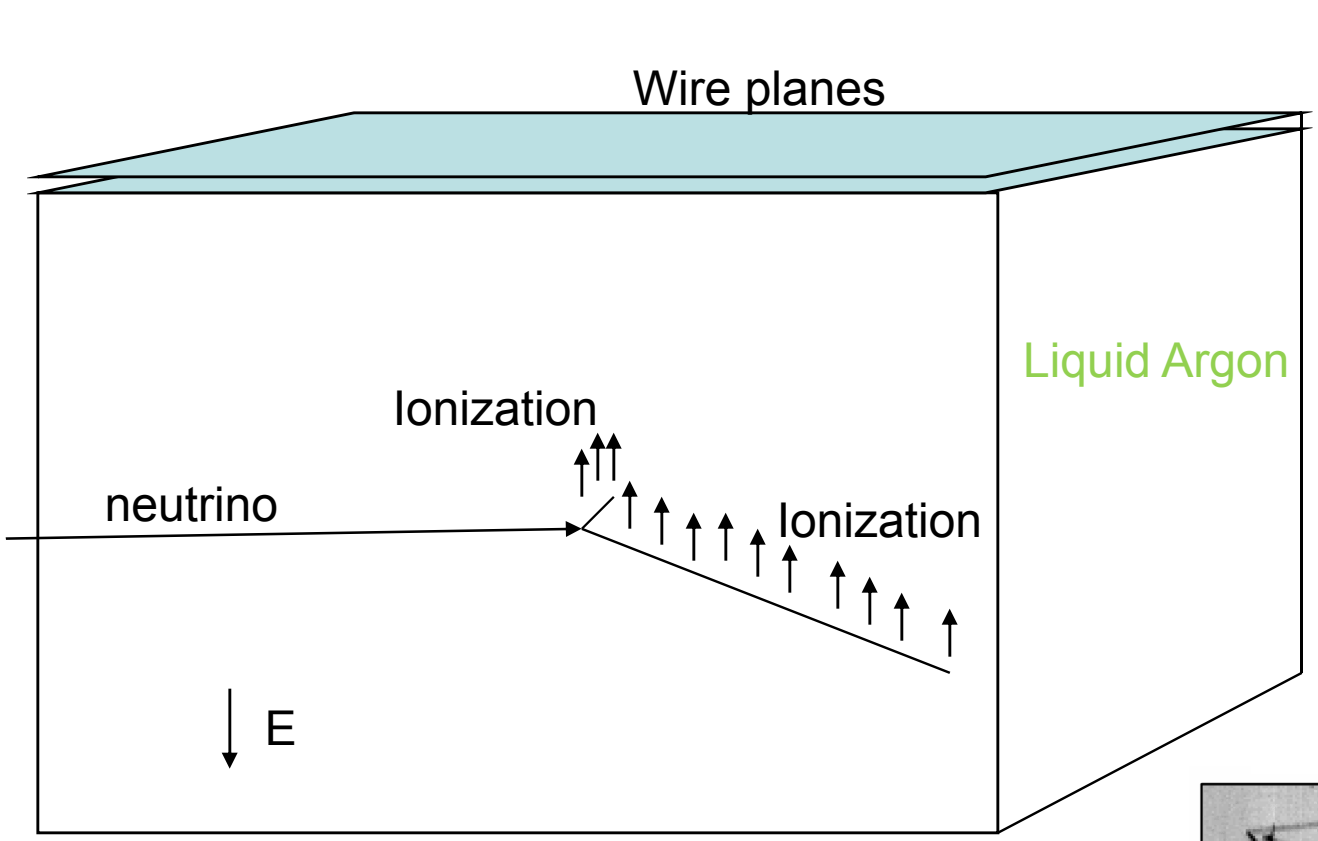
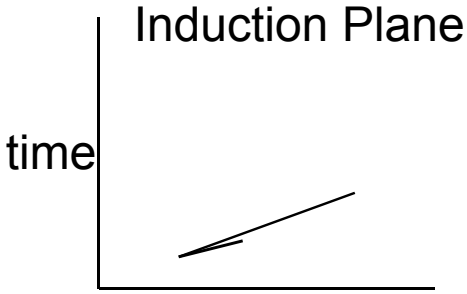
ArgoNeuT and MicroBooNE:
LArTPCs at Fermilab

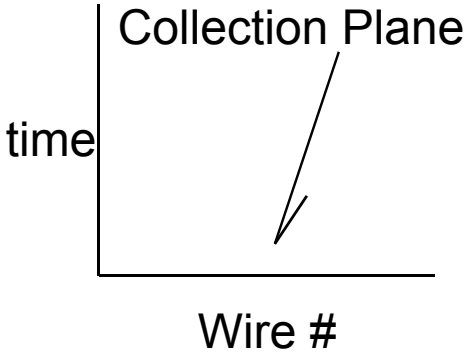
Joshua Spitz

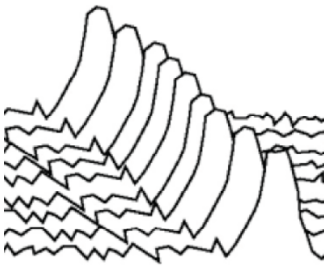
User's Meeting 6/4/2009

The LArTPC technique

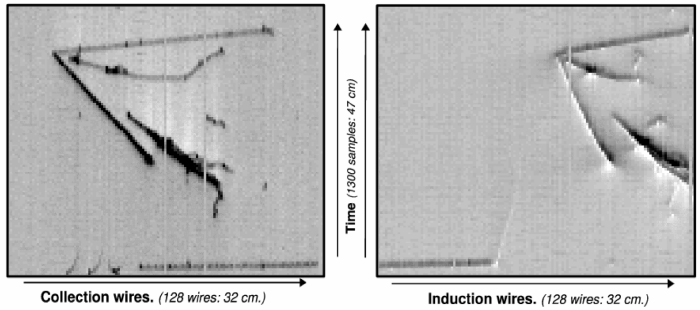








Wire pulses in time give the drift coordinate of the track



ICARUS 50L in WANF neutrino beam

induction plane + collection plane + time = 3D image of event (w/ calorimetric info)

Why Argon?

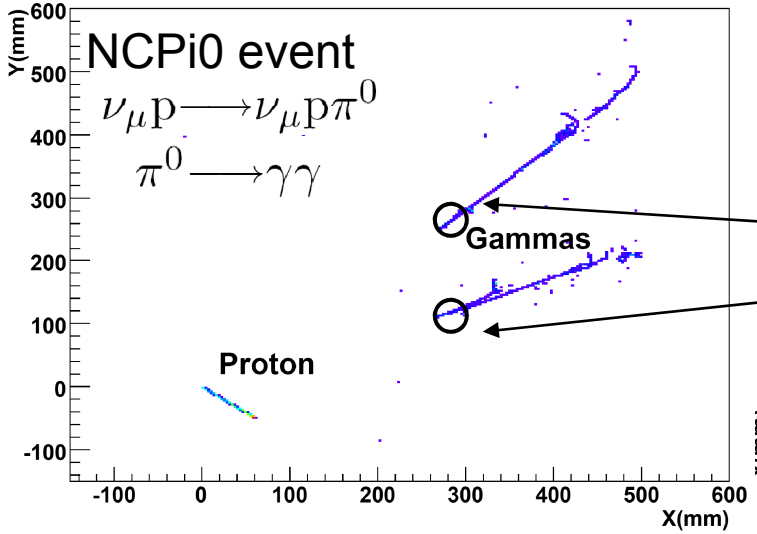
					
Boiling Point [K] @ 1atm	4.2	27.1	87.3	120.0	165.0
Density [g/cm^3]	0.125	1.2	1.4	2.4	3.0
Radiation Length [cm]	755.2	24.0	14.0	4.9	2.8
Scintillation [γ /MeV]	19,000	30,000	40,000	25,000	42,000
dE/dx [MeV/cm]	0.24	1.4	2.1	3.0	3.8
Scintillation λ [nm]	80	78	128	150	175

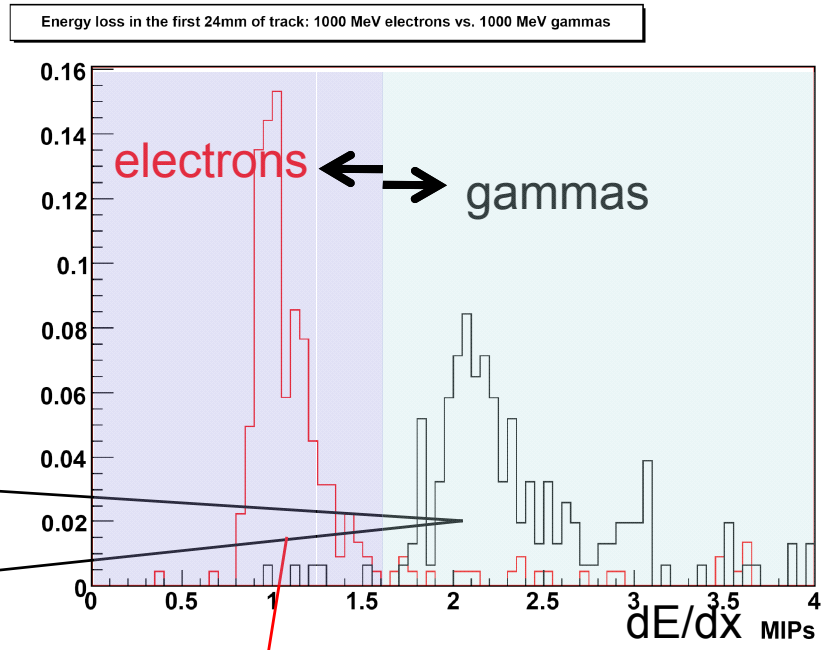
Expensive

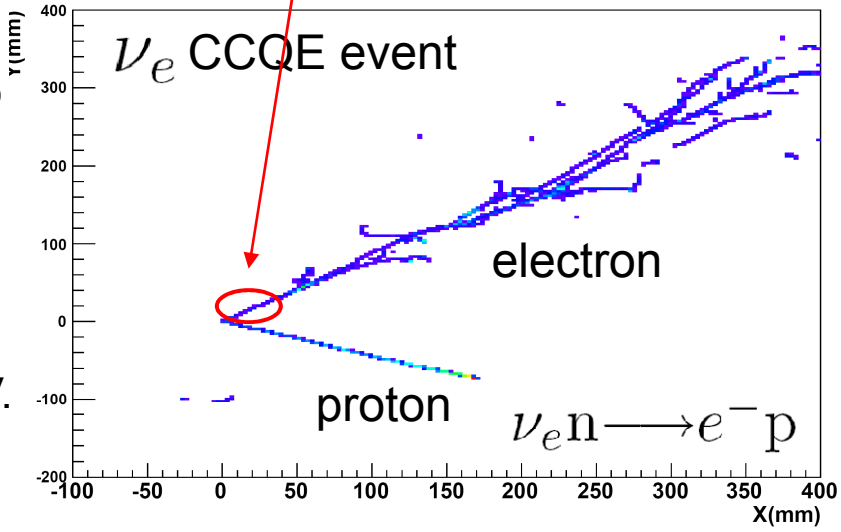
What's so great about LArTPCs?

dE/dx and energy resolution

- Monte Carlo studies show that LArTPCs can identify electron/gamma tracks with >90% efficiency.
- Extremely important for tagging ν_e correctly
  - Backgrounds: NCPi0, radiative delta decay







Position resolution

- Pixel size in ArgoNeuT= (4.0 x 4.0 x 0.3) mm^3

Low energy threshold

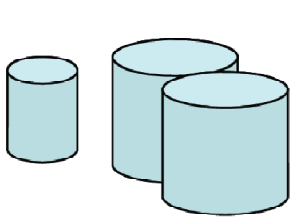
- Detection of particles with energy as low as 15 MeV.

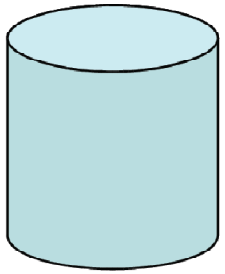
Always live

Evolution of a Liquid Argon Physics Program

R&D

Test stands



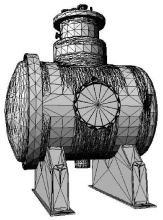


0.1 - 10 t

R&D | Physics

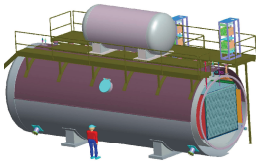
LArTPC in a neutrino beam (a la the 50 l in WANF)

0.5 t



ArgoNeuT

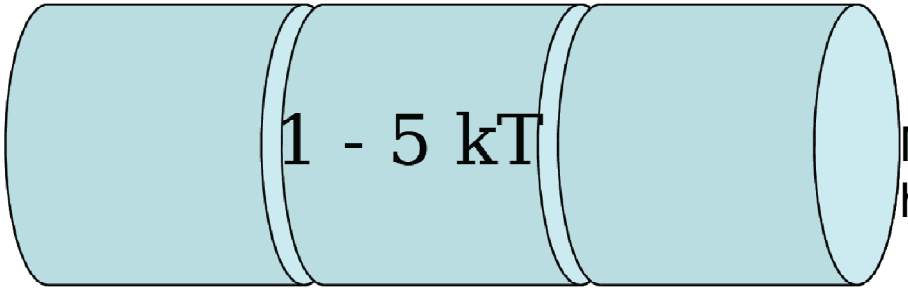
R&D | Physics



100 - 200 t

MicroBooNE

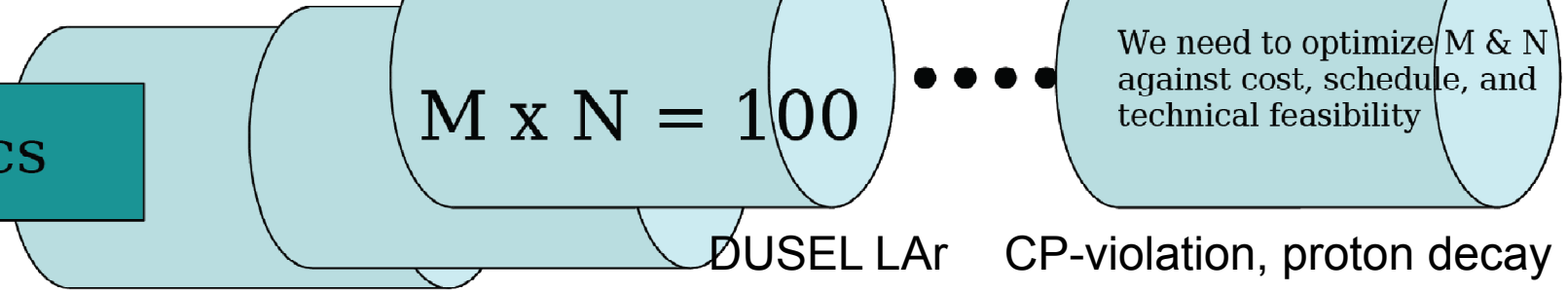
R&D | Physics



LAr5

Mass hierarchy, θ_{13}

Physics

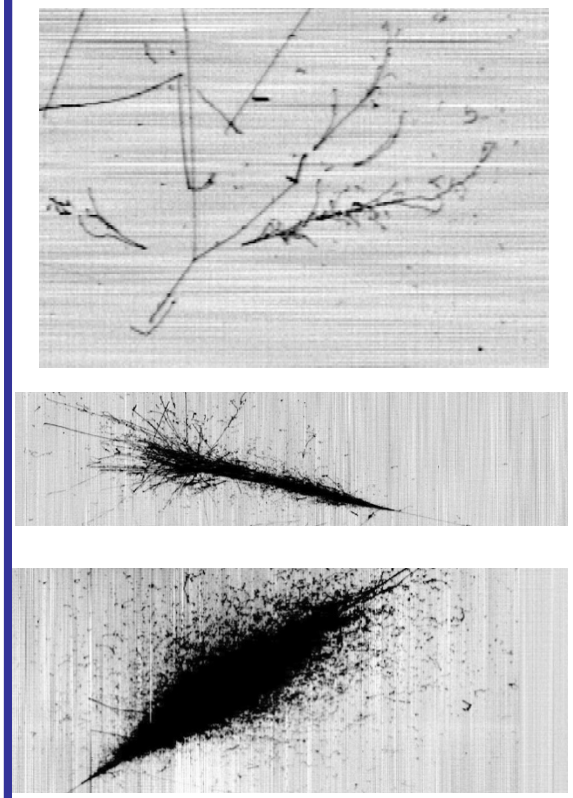


DUSEL LAr

CP-violation, proton decay

Addressing LAr challenges

- Cryogenics and Purity
  - Insulation and cooling.
  - Achieving and maintaining purity.
  - How do detector materials affect purity?
- Safety
  - Oxygen Deficiency Hazard (ODH).
  - Relief lines in a pressurized vessel.
- Electronics
  - Signal/noise.
- Detector components
  - Cryostat, field cage, HV, wires, PMTs, purity monitor,…
- Software
  - Simulated event generation, propagation, and reconstruction.



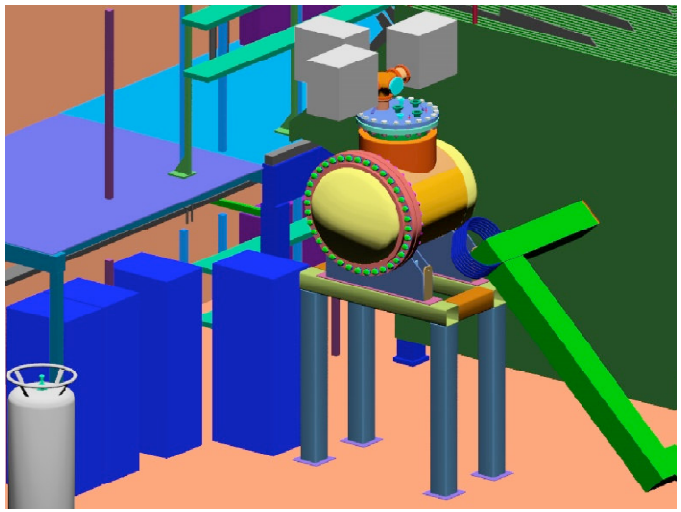
ICARUS LArTPC events

LAr test stand at FNAL

Overview of ArgoNeuT

- ArgoNeuT is the first Liquid Argon TPC (LArTPC) to go in a "low energy" neutrino beam (NuMI on-axis, peaking at ~3GeV).
- We will see 10000s of (anti-)neutrino events in the 170L TPC.
- ArgoNeuT was filled with LAr on 5/8/2009

- Goals:
  - Research and Design for future LArTPCs (MicroBooNE, long baseline neutrino oscillation, proton decay, …)
  - Beautiful, bubble-chamber-like event displays
  - Demonstrate particle ID (e.g. electron/gamma separation) capabilities of LArTPCs with dE/dx
  - Physics…



ArgoNeuT Collaboration

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University of L'Aquila

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Fermi National Accelerator Laboratory

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Gran Sasso National Laboratory

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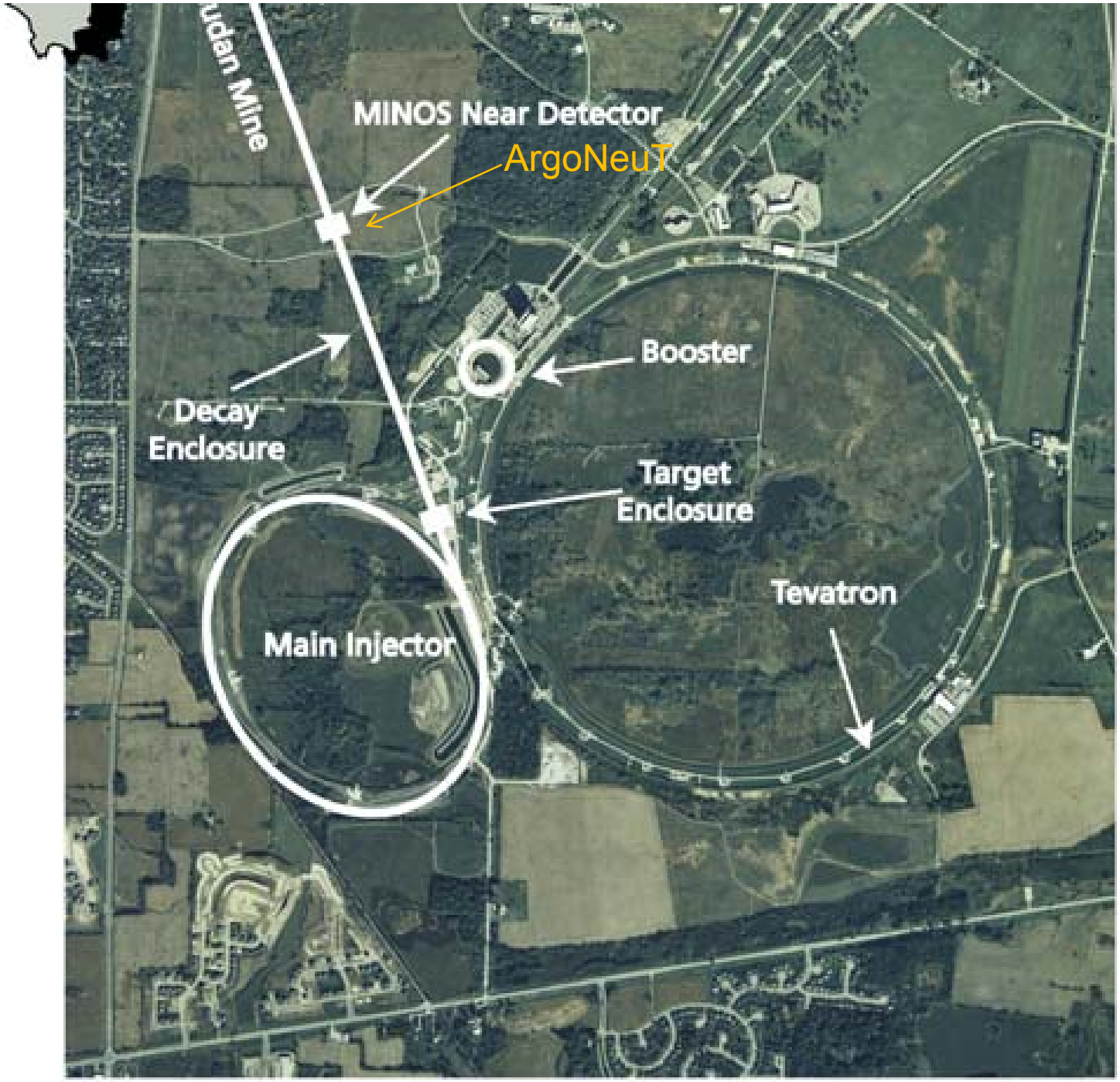
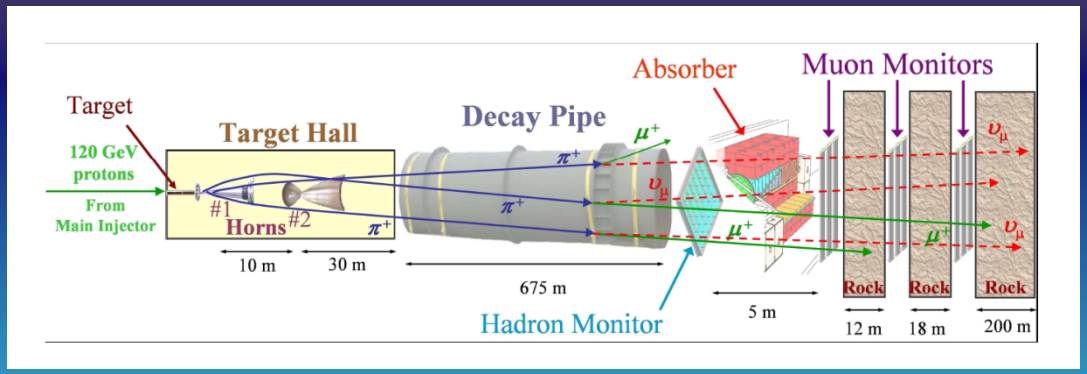
S. Kopp, K. Lang
The University of Texas at Austin

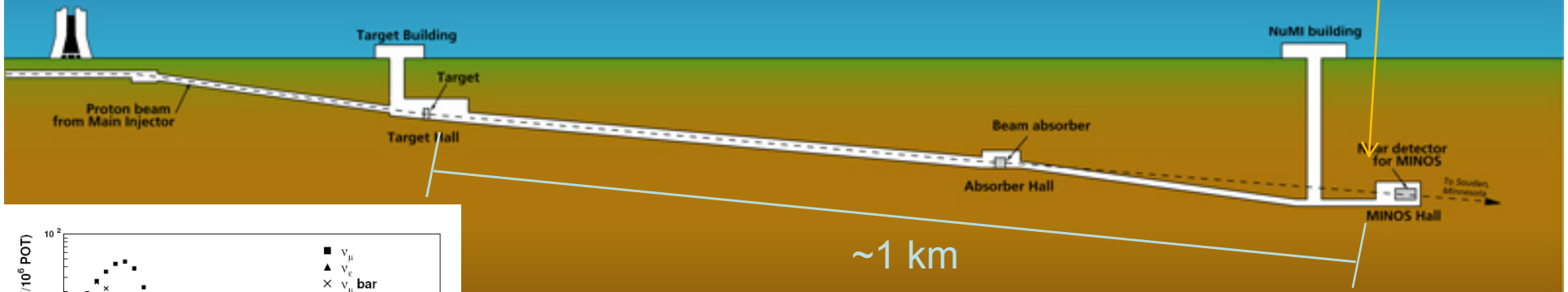
C. Anderson, B. Fleming*, S. Linden, M. Soderberg, J. Spitz, T. Wongjirad
Yale University


MINOS Near Detector
ArgoNeuT
Booster
Decay
Enclosure
Target
Enclosure
Tevatron
Main Injector
FERMILAB #98-1321D

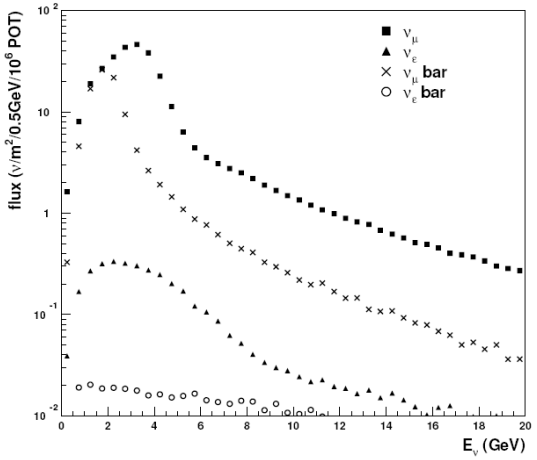
NuMI Tunnel Project



ArgoNeuT



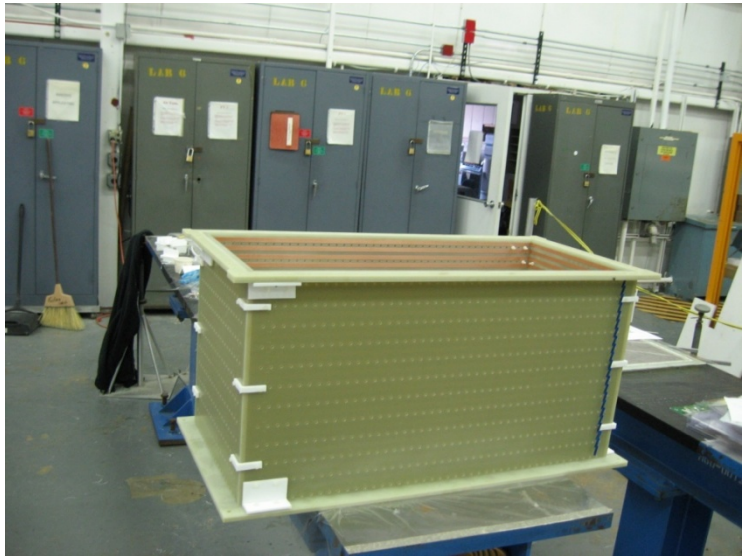
~1 km

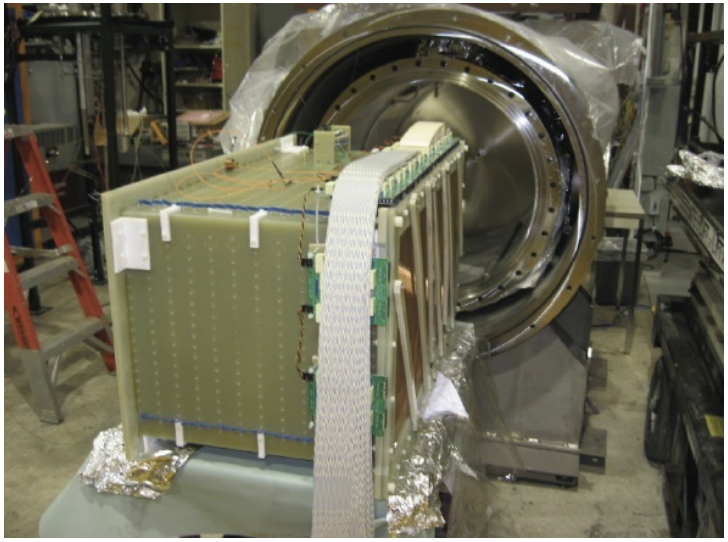


The Cryostat

ArgoNeuT TPC specs.

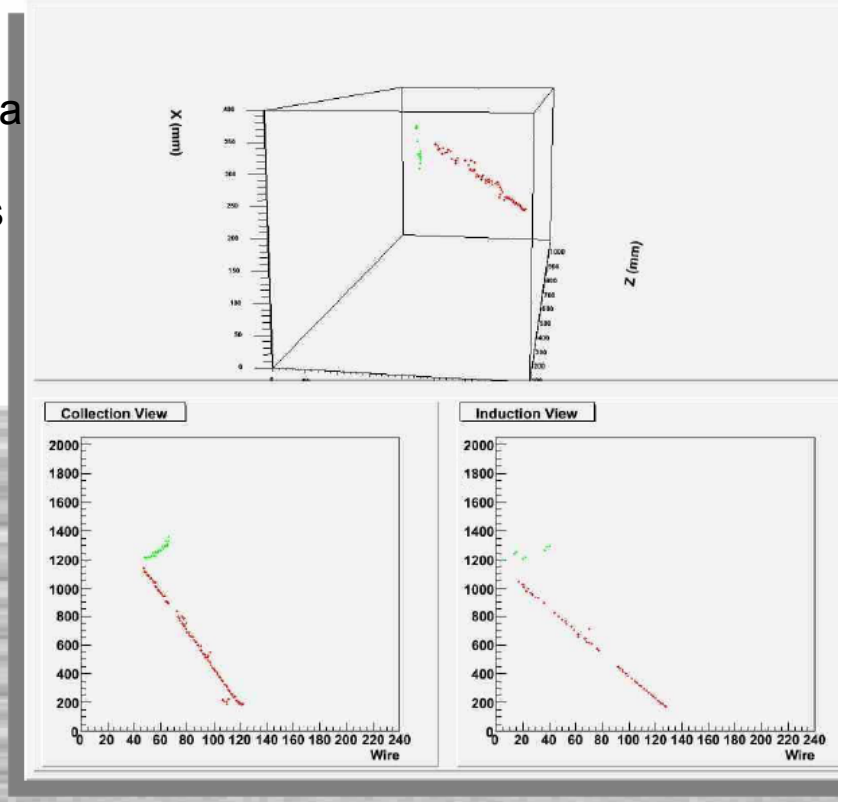
- ~170L volume
- 4mm wire spacing
- 480 channels (240 channels/plane)
- 2048 samples over 400μs (per spill)
  - ArgoNeuT will use the beam trigger to begin sampling.
- ~50cm drift distance
- ~500V/cm field
- Collection and induction wires are at ±60^{o}

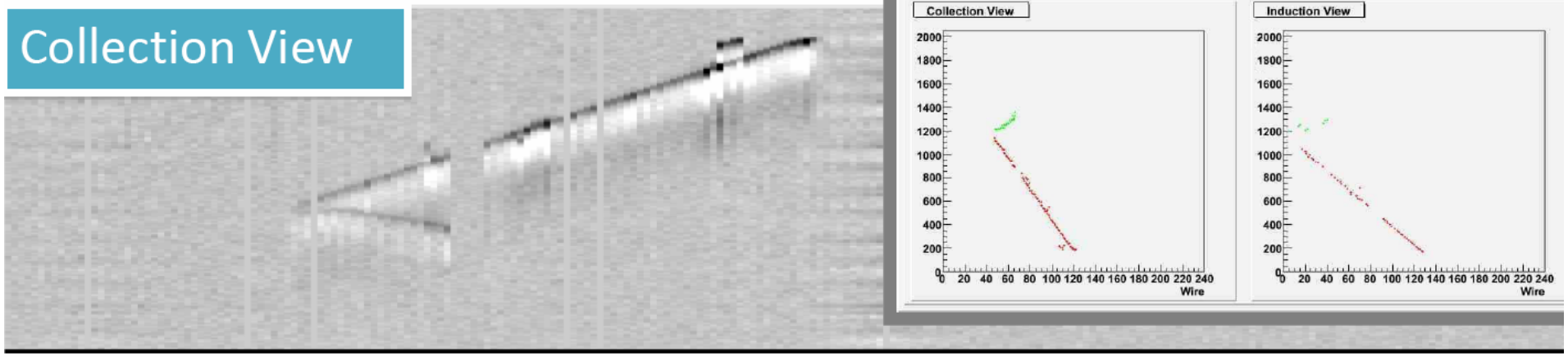


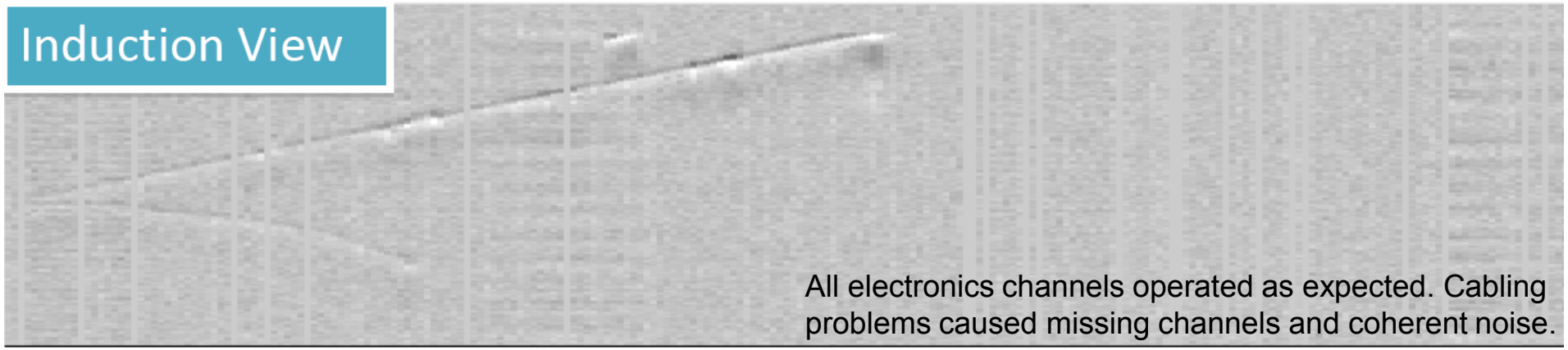


We recently completed an above-ground commissioning run where we took hundreds of through-going cosmic ray muons in the fully instrumented detector.

-Signal-to-noise was comfortable.
-Random noise was less than 0.1 mip of ionization, with a true value more like 0.05 mip or less.
-Electron lifetime = 0.4 ms w/ max drift in TPC = 0.35 ms



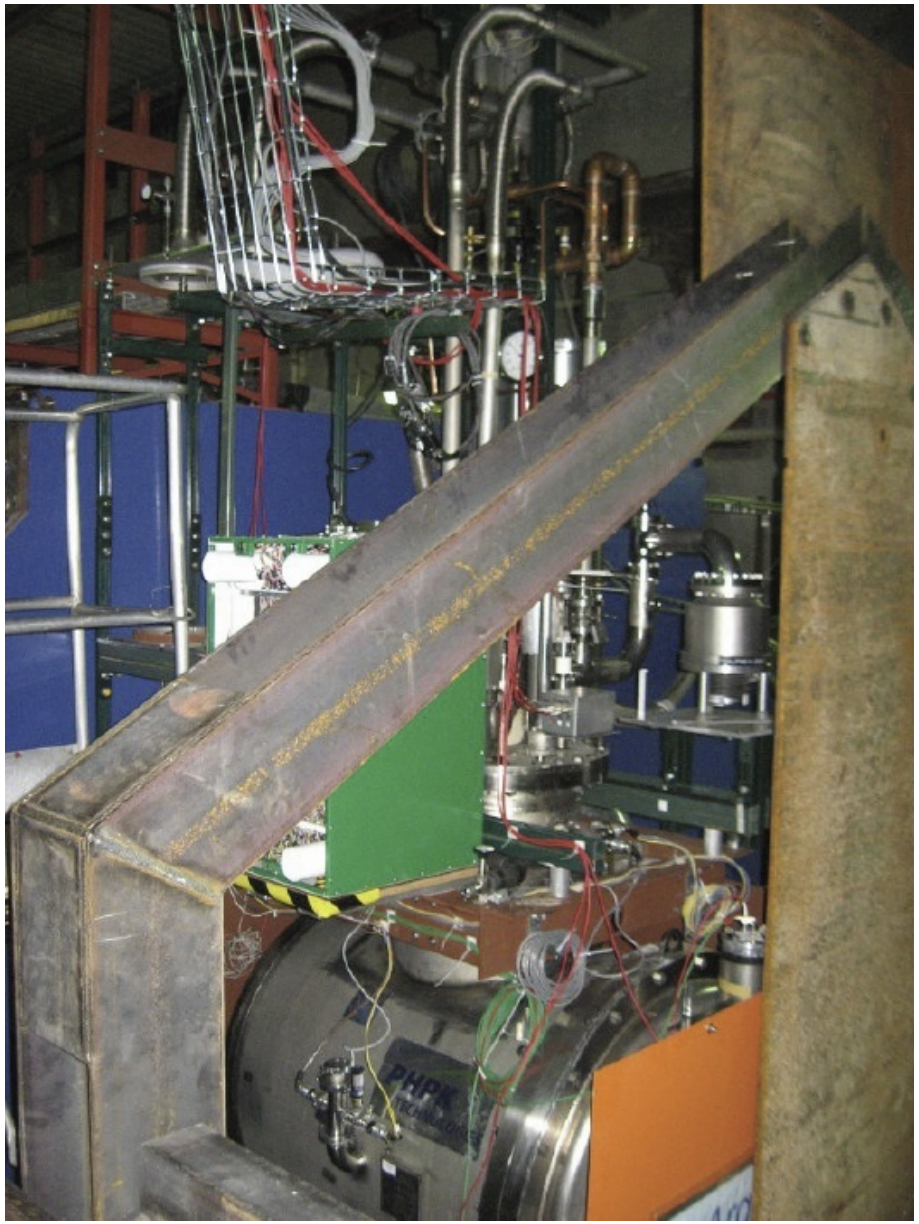




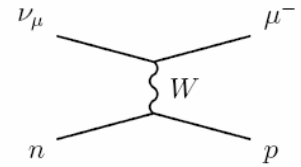
All electronics channels operated as expected. Cabling problems caused missing channels and coherent noise.

The trip underground

Arrival!

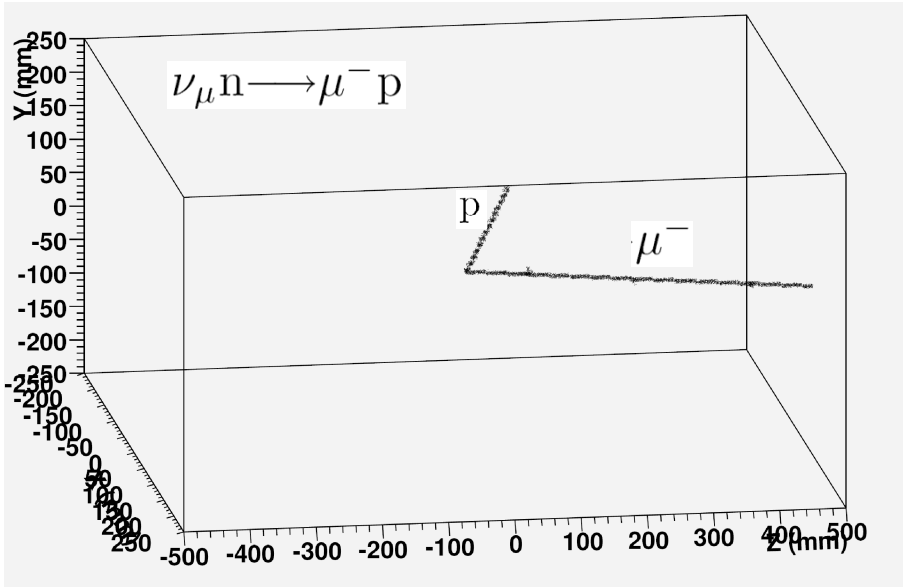


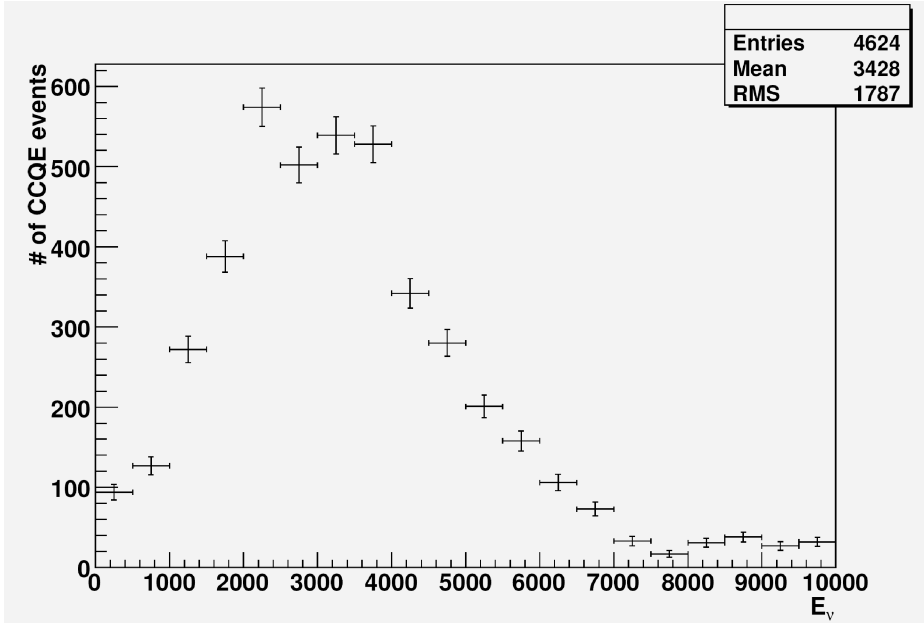
Charged-Current, Quasi-Elastic (CCQE) events in ArgoNeuT



- CCQE is considered the “golden mode” for all accelerator-based neutrino oscillation experiments.
- There are a few reasons for this:
  - The cross section is comparatively high at low (0.5-5 GeV) energy.
  - The events are simple. There are only two final-state particles with both particles easily identified and reconstructed.

- Using dE/dx and LArTPC position/energy resolution, ArgoNeuT will be able to identify and separate (CCQE-like) event-types with high efficiency.



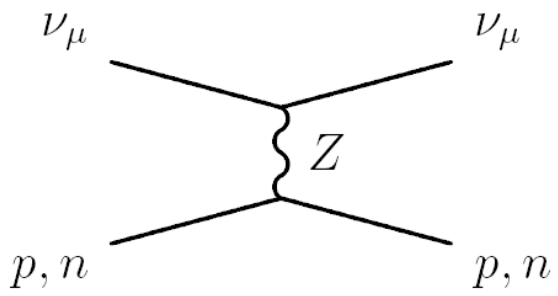


~4600 CCQE events in 180 days of running

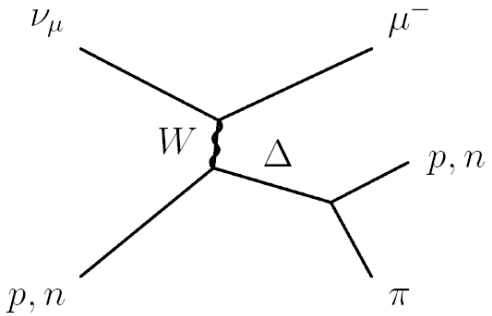
(statistical errors only are shown)

Other physics with ArgoNeuT

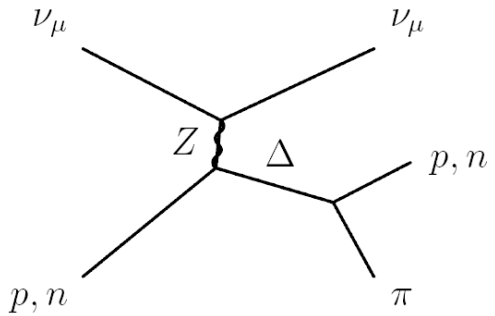
Event type	# of events in 180 days	Notes
ν_μ CC	28800	
$\overline{\nu}_\mu$ CC	2520	
ν_e CC	540	Use dE/dx to tag electron
NC	9720	
$\nu_\mu n \longrightarrow \mu^- p$ (CCQE)	4680	~50% proton containment. Will use MINOS ND for muons. Cross-section? M_A?
$\nu_\mu N \longrightarrow \nu_\mu N$ (NCE)	1420	~50% proton containment. Separating neutron and proton events? Cross-section? Δ_s?
$\nu_\mu N \longrightarrow \mu^- N \pi^+$ (CCpi+)	5490	Use dE/dx and topology to tag this channel (CCQE background)
$\nu_\mu n \longrightarrow \mu^- p \pi^0$ (CCpi0)	1850	Use dE/dx and topology to tag this channel (CCQE background)
$\nu_\mu N \longrightarrow \nu_\mu N \pi^0$ (NCpi0)	1370	Low event containment (rad length in Argon is 14 cm). Use dE/dx and topology to tag gamma



Neutral current elastic (NCE)



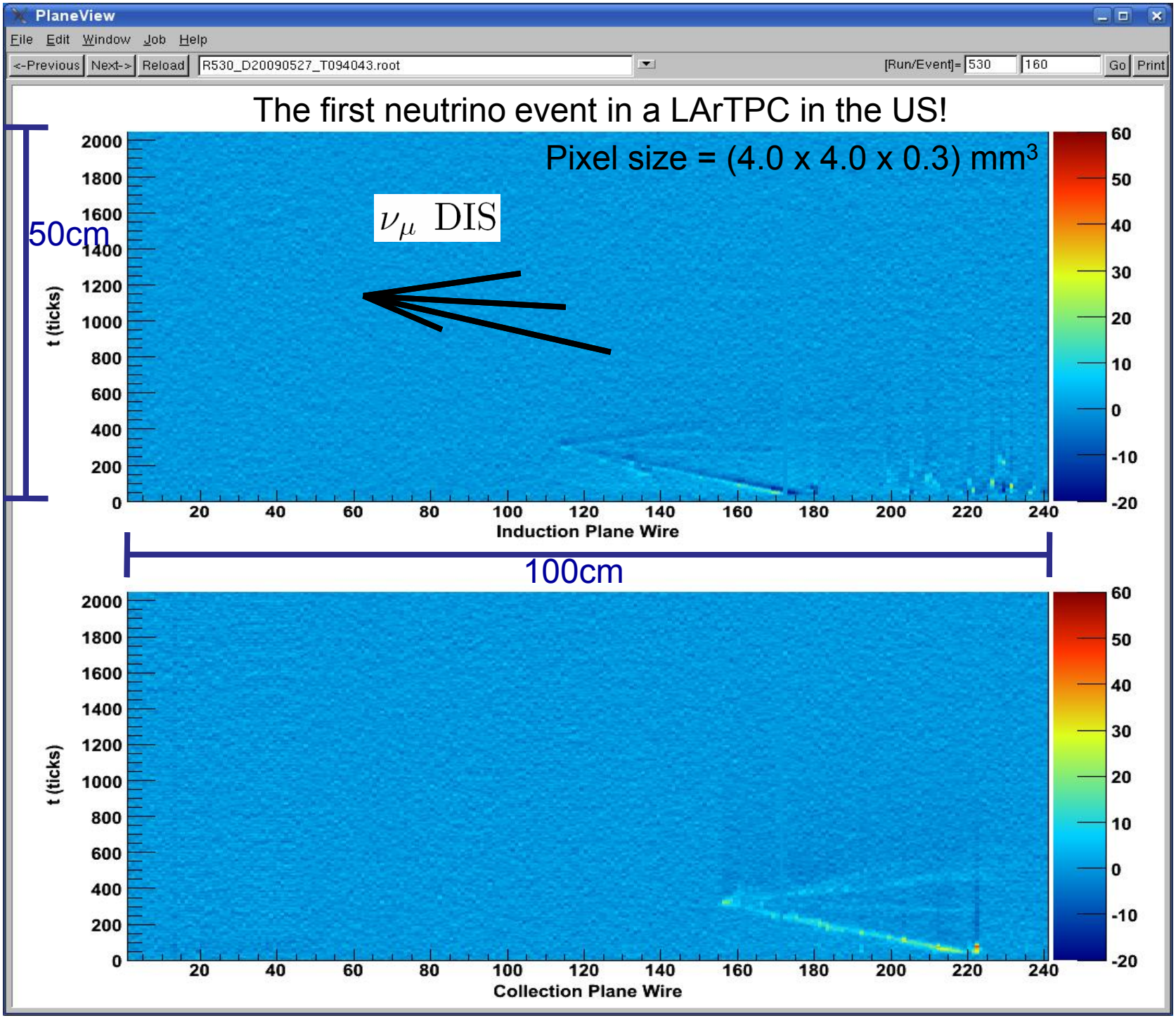
Charged current resonant (CCpi)

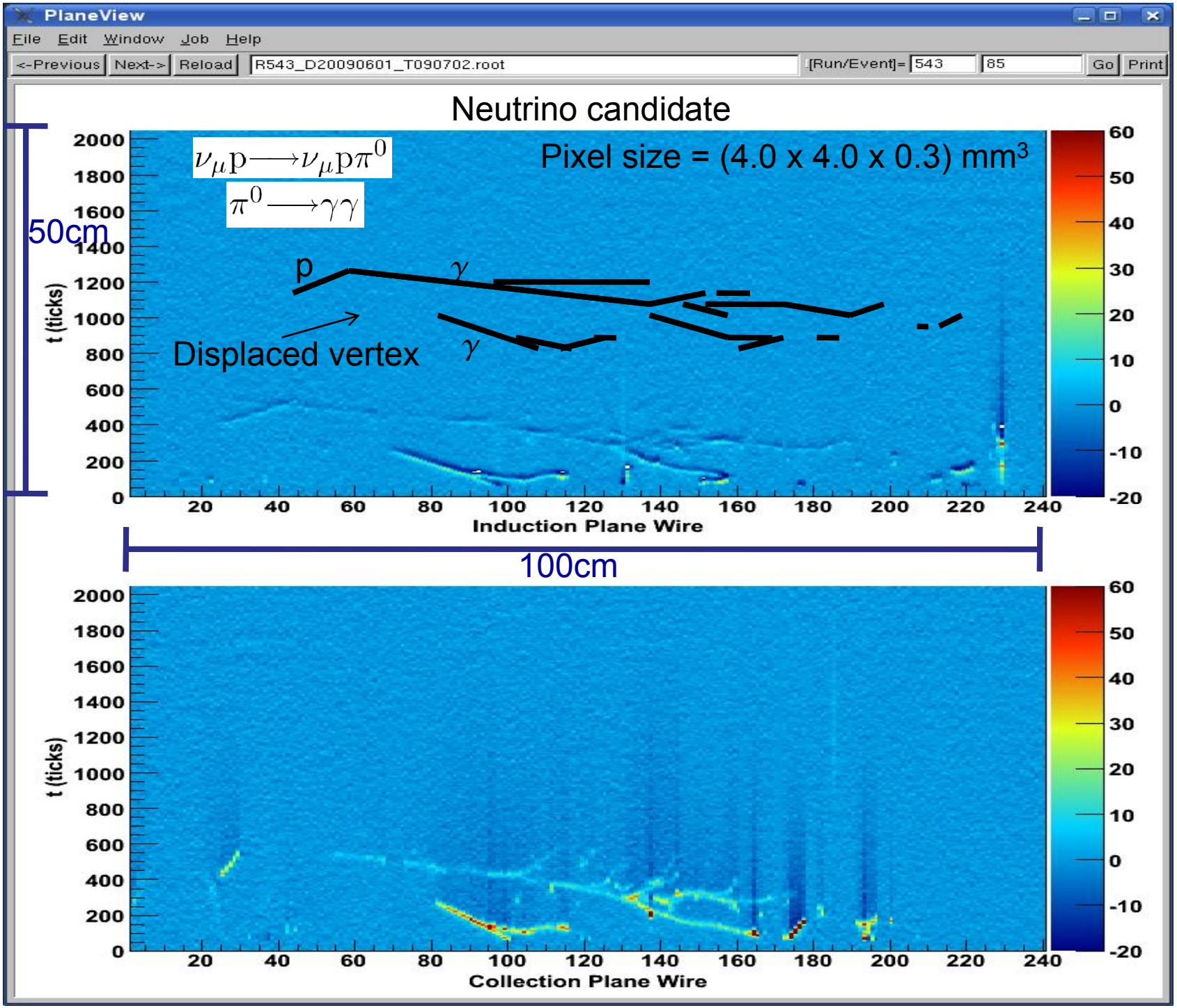


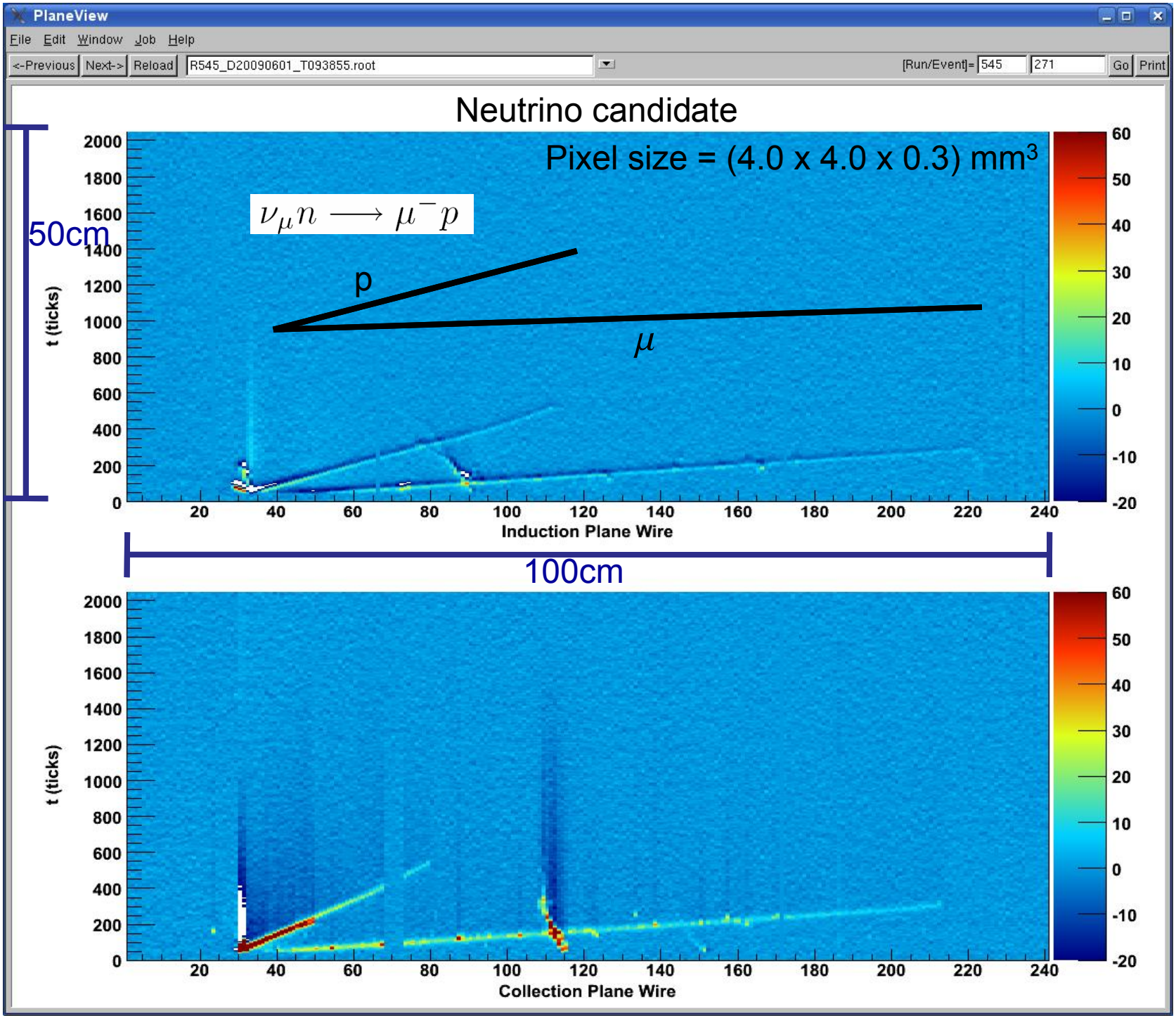
Neutral current resonant (NCpi)

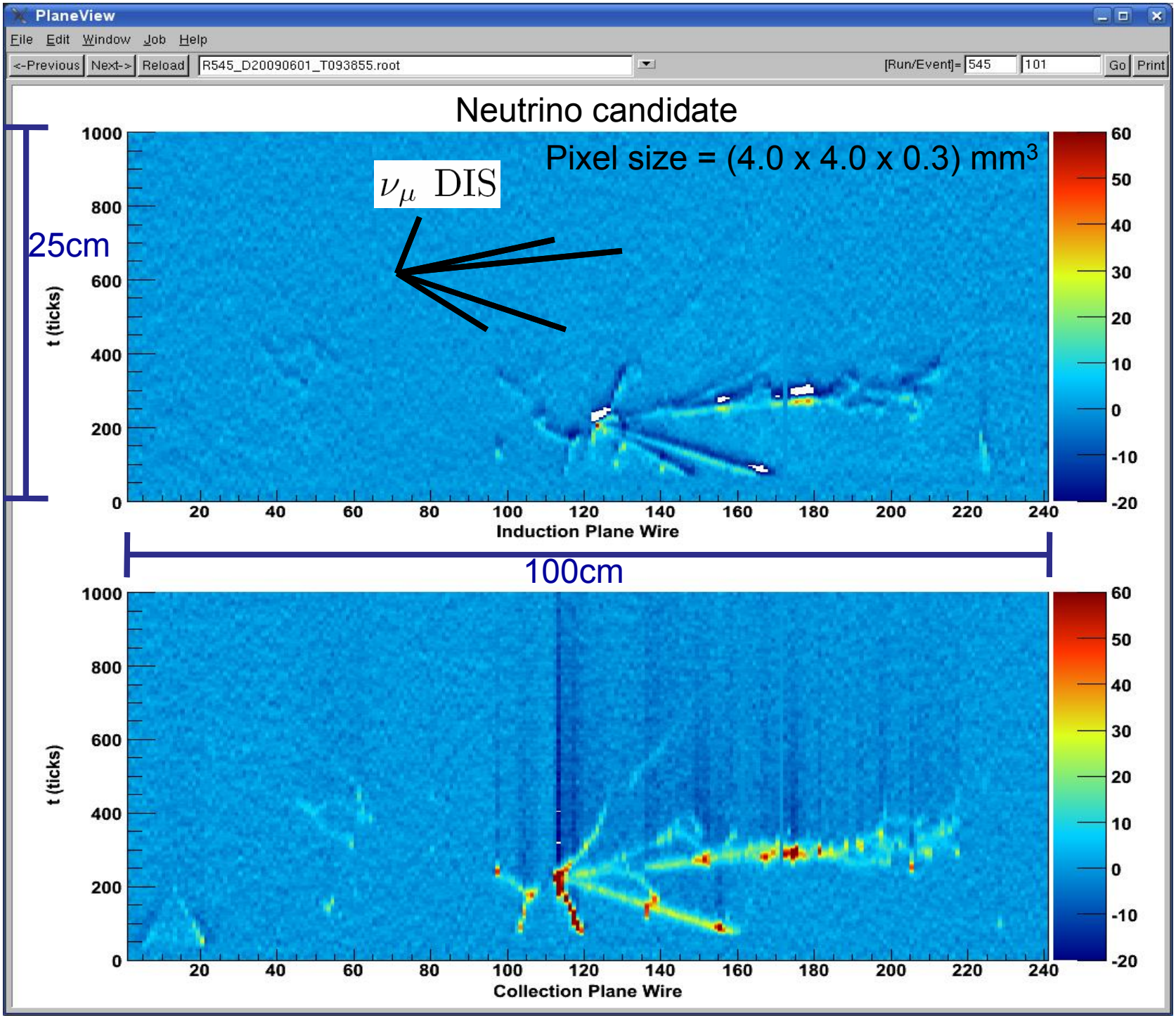
ArgoNeuT Event Displays!

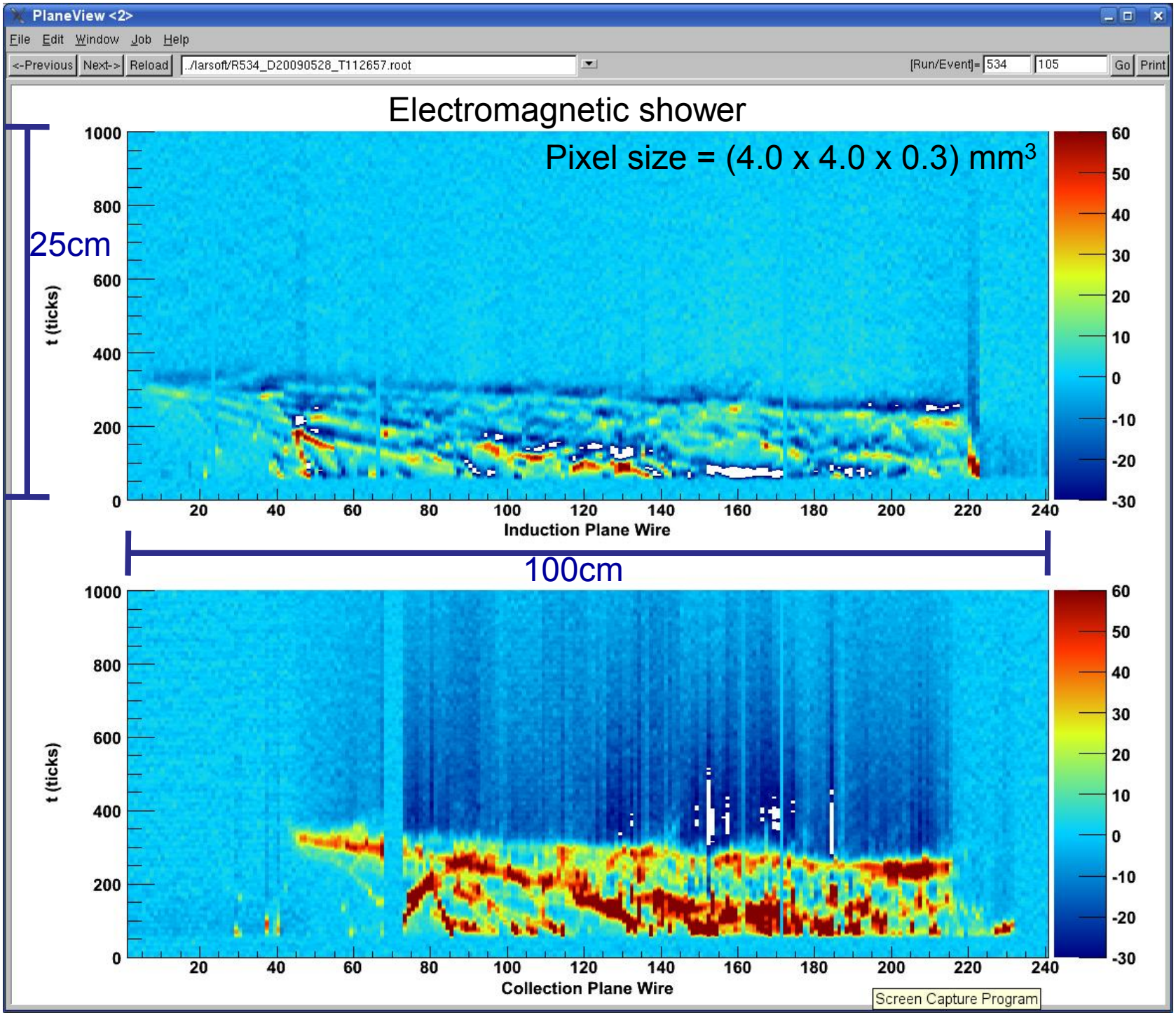
(preliminary)


PlaneView
File Edit Window Job Help
<-Previous Next-> Reload R530_D20090527_T094043.root
[Run/Event]= 530 160 Go Print
The first neutrino event in a LArTPC in the US!
Pixel size = (4.0 x 4.0 x 0.3) mm3
ν_μ DIS
50cm
t (ticks)
Induction Plane Wire
100cm
t (ticks)
Collection Plane Wire


PlaneView
File Edit Window Job Help
<-Previous Next-> Reload R543_D20090601_T090702.root [Run/Event]= 543 85 Go Print
Neutrino candidate
$\nu_\mu p \longrightarrow \nu_\mu p \pi^0$
$\pi^0 \longrightarrow \gamma\gamma$
Pixel size = (4.0 x 4.0 x 0.3) mm3
50cm
p
γ
γ
Displaced vertex
t (ticks)
Induction Plane Wire
100cm
t (ticks)
Collection Plane Wire

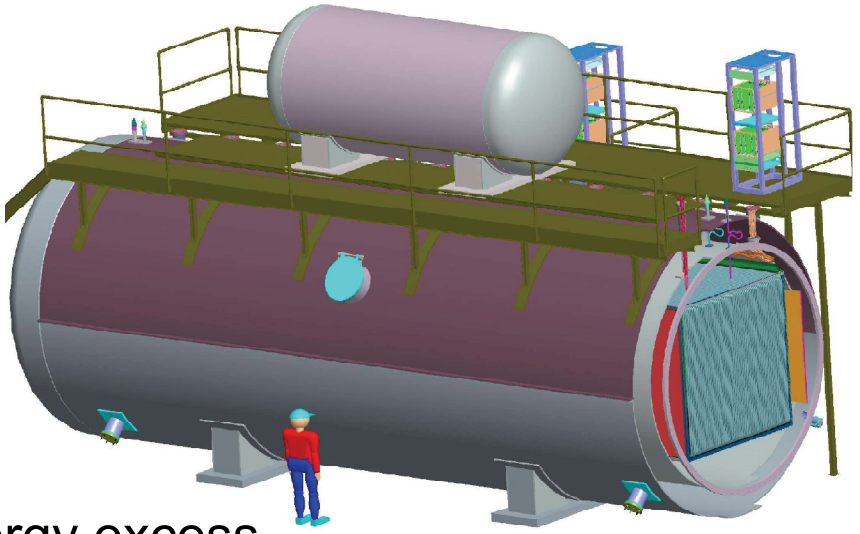

PlaneView
File Edit Window Job Help
<-Previous Next-> Reload R545_D20090601_T093855.root
[Run/Event]= 545 271 Go Print
Neutrino candidate
Pixel size = (4.0 x 4.0 x 0.3) mm3
$\nu_\mu n \longrightarrow \mu^- p$
p
μ
50cm
100cm
t (ticks)
Induction Plane Wire
Collection Plane Wire


PlaneView
File Edit Window Job Help
<-Previous Next-> Reload R545_D20090601_T093855.root [Run/Event]= 545 101 Go Print
Neutrino candidate
Pixel size = (4.0 x 4.0 x 0.3) mm3
ν_μ DIS
25cm
t (ticks)
Induction Plane Wire
100cm
t (ticks)
Collection Plane Wire


PlaneView <2>
File Edit Window Job Help
<-Previous Next-> Reload ../larsoft/R534_D20090528_T112657.root
[Run/Event]= 534 105 Go Print
Electromagnetic shower
Pixel size = (4.0 x 4.0 x 0.3) mm3
25cm
t (ticks)
Induction Plane Wire
100cm
t (ticks)
Collection Plane Wire
Screen Capture Program

The next step: MicroBooNE

- MicroBooNE is a 170 ton (70-90 ton fiducial volume) LArTPC that will begin taking data in the BNB and NuMI off-axis beams in 2012.
- Specifications:
  - 2.6m drift (500V/cm)
  - 3 readout planes (-30°, 0°, 30°)
  - 10,000 channels
  - 30 PMTs for light detection
- Goals:
  - Understand the MiniBooNE low-energy excess
  - Low-energy cross-section measurements relevant for NOvA and T2K.
  - Burst supernova neutrino detection capability
  - Sensitivity to Δ_s with $R_{NC/CC} = \frac{\sigma(\nu p \to \nu p)}{\sigma(\nu n \to \mu^- p)}$
  - R&D for future LArTPCs



	BNB	NuMI
Total Events	145k	60k
ν_μ CCQE	68k	25k
NC π^o	8k	3k
ν_e CCQE	0.4k	1.2k
POT	6×10^{20}	8×10^{20}

Expected Event Rates for MicroBooNE.

LArTPC-at-FNAL take home

FNAL has a very healthy and active Liquid Argon Program!

- ArgoNeuT is an R&D-oriented LArTPC that is currently taking data in the NuMI beamline.
  - The detector will see 10000s of (anti-)neutrino events in a wide variety of channels.
  - A CCQE cross section measurement is the top physics goal.
  - The LArTPC's ability to image neutrino events with high resolution and tag with high efficiency (dE/dx) will be demonstrated.

- MicroBooNE is an approved LArTPC-based experiment that will begin taking data in the BNB and NuMI off-axis in 2012.

R&D on the road to CP violation, Θ_{13}, proton decay, …

Backup: